Investigation of Groundwater Vulnerability Due to Leachate Infiltration in Iwaro-Oka region, Nigeria Using geochemistry and Electrical Resistivity Tomography

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Abstract

This paper presents the results of a study on impact of landfills on groundwater system of Iwaro-Oka region, Nigeria using geochemistry and electrical resistivity as a tool. The study focus on leachate dynamics originating from landfills to constrain the relationship and exchanges between conductivity of leachates and biogeochemistry to assess the fate of migratory effects of leachates in groundwater. Biogeochemical analysis of water samples from different wells were analyzed for its potability. Microbial and Physico-chemical results show evidence of micro-organisms: *Staphylococcus* sp., *Escherichia coli, Streptococcus* sp., *Basillus* sp., *Clostridium* sp., *Mycobacterium* sp. *and Micrococcus* sp. as well as elevated level of Ca, Mg, K, Na above the World Health Organization's permissible limit. Result of the ERT delineated the leachate plumes as low resistivity zones which range from 3-55 Ωm. This study indicates that leachates have invaded the groundwater system, making it not suitable for drinking.

Keywords: ERT, Groundwater, ERT, Geochemical, leachate, microbial, Iwaro-Oka, Nigeria.

Introduction

Globally, groundwater systems provide 25–40% of the world's drinking water (Morris et al., 2003). The significance of the resource is often credited to the assumption that it is free of pathogenic microorganisms (e.g., Bhattacharjee et al., 2002). However, many water borne disease outbreaks are caused by the consumption of groundwater polluted by pathogenic microorganisms (Bhattacharjee et al., 2002; Close et al., 2006; Macler and Merkle, 2000; Powell et al., 2003). Conventionally, strategies engaged to protect groundwater sources from pollution depend upon effective natural attenuation of sewage-derived microorganisms by soils (and rocks) over set back distances (Taylor et al., 2004).

In the recent times, the increasing public apprehension with groundwater management problem owing to waste disposal has generated significant hydrogeological and geochemical research activity. This research concerns, for instance, the mapping of the redox potential and electrical conductivity of the groundwater system, which are the input- parameters for the characterization of contaminant plumes and for site remediation expertise (Christensen et al., 2001; Kemna et al., 2002) The reduction-oxidation potential is susceptible to organic matter associated with landfill and its biodegradation by bacteria colonies plus the presence of electro-redox components (Christensen et al., 2001;Vayenas et al., 2002).The conductivity of groundwater system shows its ionic strength and degree of ionic mineralization, for example elevated concentration of heavy metals. Delineating these two parameters in the field of classical geochemical techniques is costly and provide only limited information.
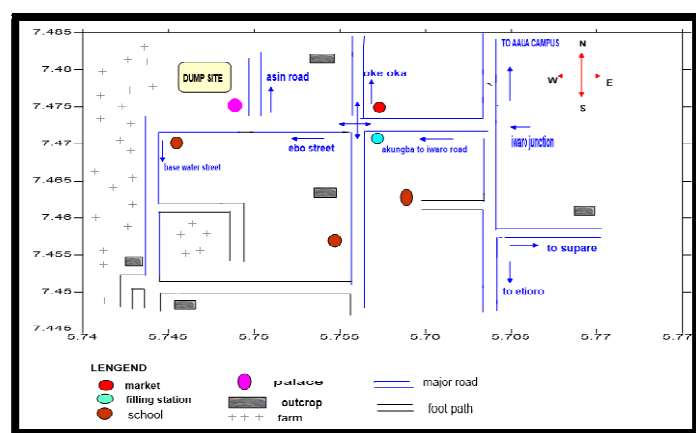

Fig. 1. Location map of the study area (Ajayi, 2012).

Distribution of micro-organisms in subsurface environments has drawn substantial attention over the past few decades due to the outbreaks of waterborne diseases associated with the microbial contamination of groundwater (Blackburn et al., 2004). Understanding the conveyance and deposition of

microorganisms in subsurface environments is critical to protect underlying groundwater from harmful microorganisms that may be present in infiltrating surface water. Several studies have been conducted to investigate the chemical, physical and biological factors influencing microbial distribution and deposition. An increase in ionic strength results in a notable increase in bacterial deposition (Bolster et al., 2001; Fontes et al., 1991; Schinner et al., 2010), with or without the presence of humic acid (Franchi and O'Melia, 2003). Equally, an increase in solution pH leads to a decrease in bacterial deposition (Yee et al., 2000). The presence of natural organic matter may also reduce bacterial deposition due to extra repulsive interaction energy (Franchi and O'Melia, 2003). Micro-orgnaisms surface charge is altered in the presence of heavy metal ions (Collins and Stotzky, 1992) and heavy metals (Helmreich et al., 2010; Prestes et al., 2006) as well as microorganisms (Selvakumar and Borst, 2006). The geochemistry of groundwater systems is hinged on the geological nature of the soil. As Rainwater runoff infiltrates into the subsurface, the two water sources mix, causing a subsequent change in Geochemistry, which may in turn alter the surface properties of both micro-organism and subsurface.

The geophysical and geochemical gathers a group of indirect and direct methods of investigation, some of which are sensitive to the physical properties characteristic to areas of accumulation of gases in the subsurface. This tool is widely used in studies of environmental diagnosis in cases such as investigation of pollutants in subsurface and groundwater from landfills (Ustra et al., 2012; Rivett et al., 2008; Kim et al., 2009; Okpoli, 2013).

This work investigate the extent of the leachate plume (contaminant) by employing an integrated use of 2D electrical resistivity, quantification of the physical and chemical properties of some water

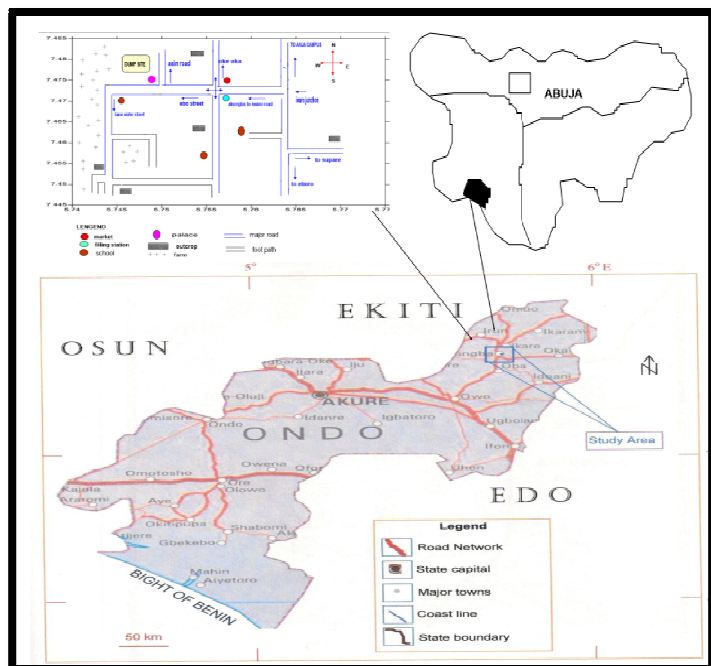samples collected from different wells in the area of study.

Fig. 2. Map of Ondo state showing the study area and the layout (modified after Ajayi, 2012).

Site Description

Site and physiography

Iwaro oka-akoko is located in Akoko southwest Local Government Area of Ondo State southwestern Nigeria. It lies within the Precambrian Complex and is bounded by longitude 5^074E -5^0755E and latitude 7^0445N -7^0485N and it covers an area of about 66 square kilometers (km^2). The study area can be accessed through a good road network running from Owo-Akungba- Iwaro Oka town.   Other roads of secondary category that are not tarred but motorable also aid accessibility in the area. Road cuts also make the rock units available for study. The northern part of the study area is characterized by a hilly topography consisting of several east-west trending ridges. Location map, geological map and study layout maps are shown in Figures 1-4. The study area belongs to the tropical rainforest region and can be

described as good and support agricultural activities. The vegetation is thick with palm trees in the direction indicating the presence of flowing river or stream. The vegetation is then highly fractured opening in rocks. Intense cultivation, habitation and deforestation have modified the vegetation. The climatic condition of the investigated area is like that of the general climate of Southwestern Nigeria, rainy season is between March and October and dry seasonal is between November to February. The temperature in the area varies between 28^oc and 38^oc with high temperature between February and April.
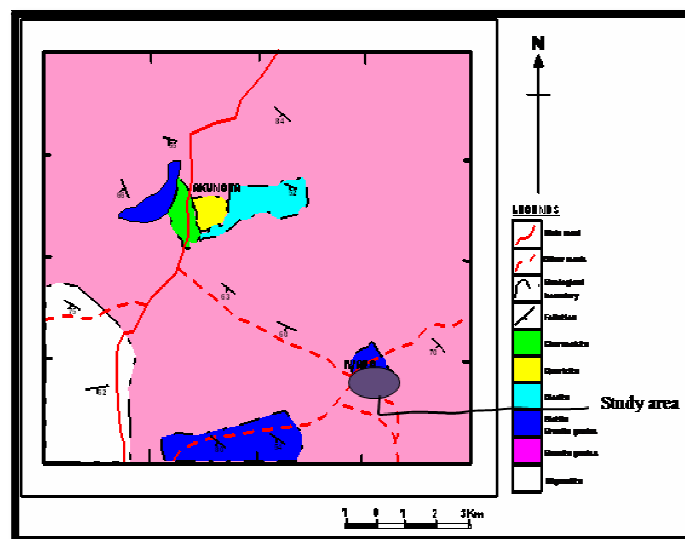

Fig. 3. Geological Map of the Study Area (Ajayi, 2012).

Geology and Hydrogeology

The survey area is underlained by the Precambrian basement complex rock of southwestern Nigeria. The basement rock exposures are however found as low land outcrop in few place within the survey area particularly where basement in shallow and erosional activities are active. However, according to (Rahaman and Ocan, 1978) the area is underlained by migmatite-quartite complex with the granite-gneiss being the major unit include charnockite ,quartzite, Diorite, Biotite. The area is sandwiched between two parallel prominent E-W ridges/inselberg of granite

gneiss composition found at the north, south and eastern ends. The feature create a broad valley for groundwater resources development, generally in a typical basement complex area, groundwater is usually contained in the weathered column and fractured/fissured, sheared or jointed/faulted basement column. The geological processes in the study area enhances the leaching of contain plumes into the aquifer. Hence, the geological condition of the study area favors groundwater accumulation.
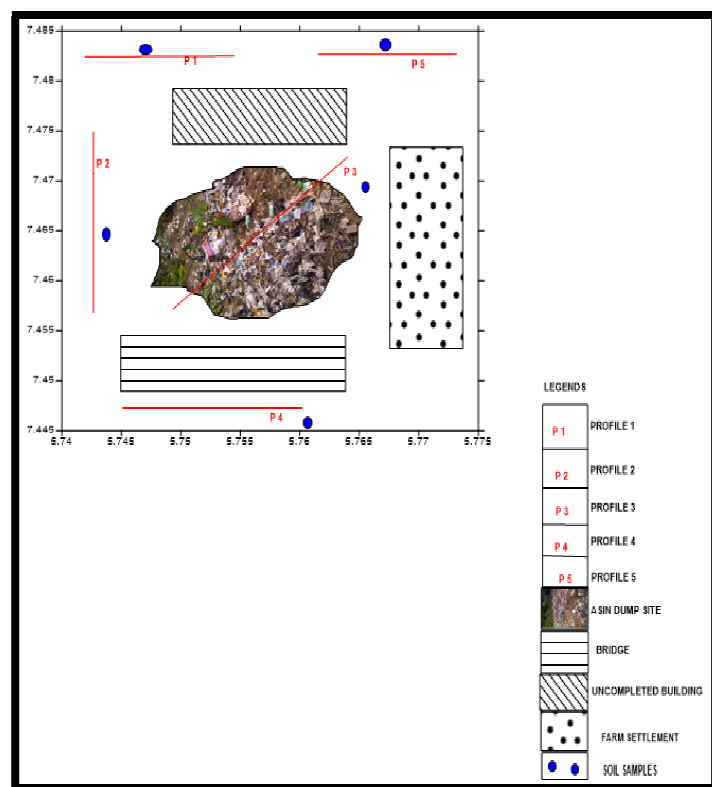

Fig. 4. Acquisition map of the study area (Ajayi, 2012).

Materials and Methods

2D Electrical ResistivityTomography

Two-dimensional (2-D) resistivity tomographies were effected in the landfill site. These tomographies imaged the vadoze zone, the aquifer system primarily aquitard, which are the units with contrasting resistivity and conductivity determined by ERT with the electrical conductivity of the

contaminated wells due to leachates plume. ABEM Multi-electrode Terameter (SAS 1000C) was used with the dipole-dipole array configuration and a set of 64 standard stainless steel inserted 2-5m into the ground. Thus the dipole-dipole array is very sensitive to horizontal changes in resistivity, which implies that is good in mapping vertical structures, such as dykes and cavities (Loke, 2004).The data got from the field were converted to apparent resistivity using the formula below: The electrodes were moved from one end of the profile to the other in a lipfrog manner to achieve continuous horizontal coverage of the subsurface. The apparent resistivity measurements were inverted using the Res2DINV inversion software.

Water quality analysis

In order to assess the level of groundwater contamination by the solid waste leachate, water quality analysis was conducted on (18) water samples from eighteen hand dug wells around the dump site. The water samples were analyzed for physical and chemical parameters. The chemical paremeters include the test for cation and the anion while the physical parameters tested for are: Temp (^{o}C), Conductivity (S/Cm), ph, Total Dissolved Solid (Mg/l) and Turbidity (FTU). The cations include: Ca, Mg, K, Na, Pb, As, Fe, Cd, Hg while the anions are: Cl^- and CO_3-.

Procedure for Chemical Parameters
Procedures for the anions

Cl^- : 100ml of the sample was pipetted into a chemical flask and 1.0ml K_2O_4 (Potassium Chromate) solution indicator was added, it was then titrated with constant stirring with 0.028M $AgHO_3$ until the suspension becomes pink. The pinkish colour shows the end point from which the concentration of Cl^- can be determined.

CO_3- : 40ml of the sample was pipetted into the conical flask and it was analysed with 3.5ml of $Bacl_2$

gelatine reagent and left for 30 seconds for colour development. The absorbent was read at 45mm calorimeter. This is determined by matching the result with standard calibrated graph where the corresponding value of 45mm on the horizontal.

Procedure for cations

Atomic Absorption Spectrometer (AAS) was used for the determination of the cations. The AAS entails the aspiration of samples into flames, where it becomes atomized. A light beam if the flame is directed through the flame into a monochromatic and unto a detector. The detector then measures the intensity of light absorbed by the atomized element in the flame thus the amount of the concentration of the element in the sample.

The cathode lamp of the elements is put in position and the instrument characteristics wavelength selector. Standard solution of the element to be determined is first prepared and the absorbance measured at the selected wavelength against the concentration of the standard to obtain a calibration graph. The absorbance has linear calibration with the concentration. The absorbance of the sample is then obtained and compared with the calibration curve so that the sample concentration can be determined.

Procedure for Physical Parameters
Ph Determination

Electronic Ph meter (Digital) mode, Exner GMBH, D4040 NEUSSI was used. It has a combined electrode and it was standardized using buffer solutions of Ph 4 and 9.

After standardization, the electrode was rinsed dish-led water and it was dipped into the sample and the value was recorded.

TDS Determination

A clean crucible dish of suitable size was placed in an oven at temperature of 103-150°C until constant weight was noted. 100ml of the water sample was poured into the dish after shaking thoroughly and evaporate at temperature between 103-150°C. It was cooled to room temperature and weighed. It was returned into the oven dried further for 10-20 mins. Weighed after cooling to room temperature, this was repeated until constant weight was obtained.
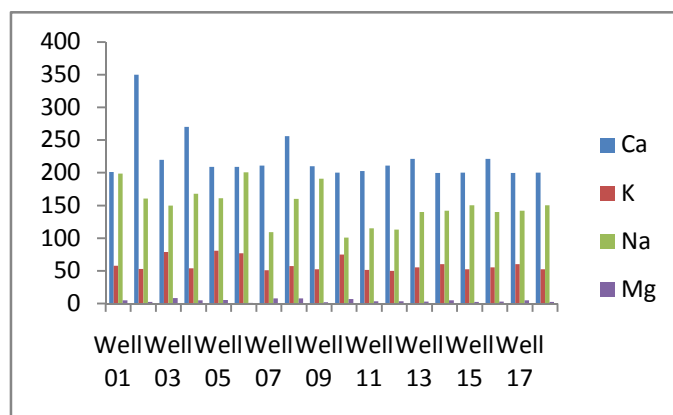

Fig. 5. Bar chart representing Ca, K, Na, and Mg.

Turbidity Determination

Meter was rinsed with the portion of the water to be tested and later emptied and replaced the cover rotated knob until slides touch while it did not observe last visible light spot and was read direct off scale for turbidity unit.

Temperature Determination

This parameter was determined with a thermometer having a reading of 0.00°C- 100°C. The thermometer was placed vertically immersing the bulb containing the mercury in the water sample on the field immediately after collision. It was allowed to stand still and the temperature was taken and recorded.

Microbial test methodology

The Microbial Limit Test is designed to perform the qualitative and quantitative estimations of specific viable microorganisms present in samples. It includes tests for total viable count (bacteria and fungi) and *Escherichia coli*. The most care must be taken in

performing the tests, so that microbial contamination from the outside can be avoided. When test samples have microbial activity or when they include antimicrobial substances, these microbial properties must be eliminated by dilution, filtration, neutralization, inactivation, or other appropriate means. The tests should be conducted for samples prepared by mixing multiple portions randomly chosen from individual ingredients or products. When samples are diluted with fluid medium, the tests must be conducted quickly. Careful attention must be paid to the effective quality control and the prevention of biohazard.
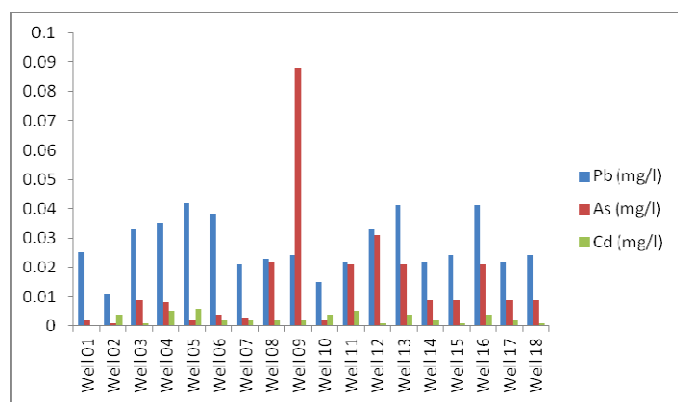

Fig. 6. Bar chart representing Pb, As, and Cd.

Procedure for the microbial test

10 ml of each samples was taken with the addition of lactose broth medium to make 100 ml, and then incubate for 24-72 hours at 30^0C-50^0C. When the growth of microorganisms in the tube is observed, the tube was shaken slightly, a portion of the fluid using an inoculating loop was streak on MacConkey agar medium, and incubate for 18-24 hours at 30^0C-35^0C. The plate was then examined for suspicious colonies. Absence of red-brick colonies of Gram-negative rods surrounded by a reddish precipitation zone shows the sample to be negative. Colonies meeting the above description are then transferred individually on the surface of EMB agar medium and incubate for 18-24

hours at 30^0C-35^0C. Sample with colonies showing no metallic sheen or a blue black color under transmitted light is determined to be negative. For suspected colonies on the plate, Microbial Loads of these water samples were done using serial dilutions and pour plate techniques according to the method of Olutoye et al., (2005). Each of the water samples was serially diluted and plated. The cultures were incubated at 37^0C for 24hrs. After incubation, the colonies were enumerated as shown in Table 8 to know the total bacterial count of the water samples.
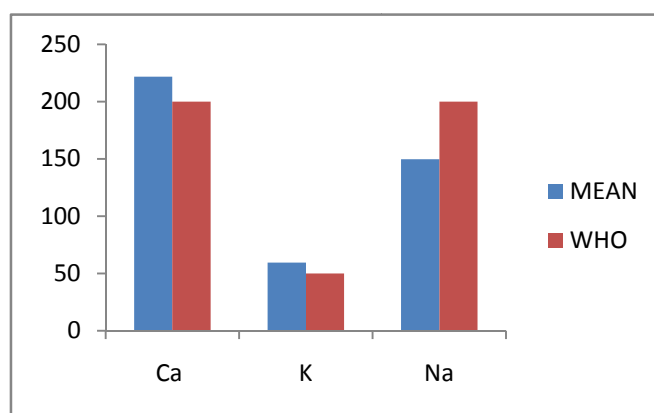
Fig. 7. Bar chart representing Table 2 compared with W.H.O.

Results and Discussion

Physico-chemical result of the water sample

Eighteen representative water samples from the study area were collected for the determination of the cations, anions and physical parameters of the water. The result of each of the physico-chemical parameters are presented in the Table 1-6

Chemical properties of the water

Cations and anions carried out on the water samples include: Ca, Mg, Na, Pb, As, Fe, Cd, Cl⁻, and Co. The result of each of the parameters was compared with the WHO standard of 2004 version and

Table 1. Concentration of Cations in the water samples

SAMPLE CODE	Ca (mg/l)	Mg (mg/l)	K (mg/l)	Na (mg/l)	Pb (mg/l)	As (mg/l)	Fe (mg/l)	Cd (mg/l)
Well 01	201.1	5.051	58	199	0.025	0.002	1.013	
Well 02	350.3	2.261	53	160.5	0.011	0.001	0.337	0.004
Well 03	220	8.081	78.9	150	0.033	0.009	0.132	0.001
Well 04	270.1	5.008	53.9	168	0.035	0.008	0.359	0.005
Well 05	209.1	5.198	81	160.99	0.042	0.002	0.117	0.006
Well 06	209.1	1.087	76.9	200.89	0.038	0.004	0.213	0.002
Well 07	211.1	7.593	50.9	109.01	0.021	0.003	1.002	0.002
Well 08	256.1	7.593	57.1	160.01	0.023	0.022	0.321	0.002
Well 09	210.2	1.884	52.33	190.89	0.024	0.088	0.248	0.002
Well 10	200.2	6.892	74.9	101	0.015	0.002	1.001	0.004
Well 11	202.9	3.5	51.22	115.1	0.022	0.021	0.351	0.005
Well 12	211	3.42	49.99	113	0.033	0.031	0.3	0.001
Well 13	221.4	2.89	55.23	140.22	0.041	0.021	0.5	0.004
Well 14	199.9	5.001	60.11	142.11	0.022	0.009	1	0.002
Well 15	200	2.4	52.2	150.11	0.024	0.009	0.301	0.001
Well 16	221.4	2.89	55.23	140.22	0.041	0.021	0.5	0.004
Well 17	199.9	5.001	60.11	142.11	0.022	0.009	1	0.002
Well 18	200	2.4	52.2	150.11	0.024	0.009	0.301	0.001
MEAN	221.87	4.341	59.62	149.62	0.027	0.0150	0.4997	0.00272

Table 2. Mean value for the cations compared with W.H.O.

Parameter (mg/l)	Ca	Mg	K	Na	Pb	As	Fe	Cd
Mean(mg/l)	221.8	4.34	59.6	149.62	0.027	0.015	0.499	0.0027
W.H.O	200	0.20	50	200	0.01	0.01	0.01	0.003

inferences were made on the effect of the water on the people and animal taking it.

Calcium (Ca): The result of calcium as shown in the Table 1 ranges from 199.9mg/l to 350.3mg/l and the average of 221.87mg/l as shown in Table 2.

The measured parameter showed concentrations exceeding the permissible limits (W.H.O, 2004) which signified groundwater contamination. The high concentration of calcium can also be shown in Figure

5. The mean value of calcium is compared with W.H.O in Figure 7 which is also found to exceed the W.H.O standard. From the specification of W.H.O as shown in the Table 7, excess of calcium in the body causes indigestion of fat hence the high concentration of the calcium in this water samples can result in indigestion of fat.

Table 3. Concentration of Anions in the water samples

Sample Code	Cl-	CO_3-
Well 01	120	1
Well 02	167	3
Well 03	156	5
Well 04	157	6
Well 05	156	1
Well 06	154	0
Well 07	156	3
Well 08	153.11	2.48
Well 09	120	1
Well 10	167	3
Well 11	156	2
Well 12	157	4
Well 13	156	1
Well 14	154	0
Well 15	156	1
Well 16	167	3
Well 17	156	2
Well 18	157	4
MEAN	153.6172	2.36

Table 4. Mean values for the Anions in the water samples

Parameter (mg/l)	Cl-	CO_3-
Mean (mg/l)	153.61	2.36

*Magnesium (Mg)***:** The result of the magnesium as shown in the Table 1 ranges from 1.08 to 8.08mg/l and with the average of 4.34mg/l as shown in Table 2.

The measured parameter showed concentration exceeding the permissible limits (W.H.O, 2004) which signified groundwater contamination. The high concentration of magnesium is shown in Figure 5. From the specification of W.H.O as shown in Table 7, the intakes of this water with its high concentration will result in the liver or kidney disease.

*Potassium (K)***:** The concentration of potassium ranges from 49.9mg/l to 81mg/l as shown in Table 1 and the average of 59.6mg/l as shown in Table 2.

The high concentration of potassium is shown in Figure 5. The comparison of this result with the W.H.O. standard as shown in Figure 7 shows that it exceeds the standard hence, they have effect on the blood pressure.

*Sodium (Na)***:** The result of sodium ranges from 101 to 200.8mg/l as shown in Table 1 and the average of 149.6mg/l as shown in Table 2 falls below the W.H.O standard. The low concentration of sodium is shown in Figure 5.

When compared with W.H.O. as shown in Figure 7, the mean value of sodium in the water samples fall below the W.H.O standard which implies that the intake of this water is safe because an increase in the acceptable level can increase the risk of cancer. The low concentration of this parameter is due to the lower free radicals exchange of sodium cations present in the groundwater.

*Lead (Pb)***:** The result of this parameter ranges from 0.011 to 0.042mg/l as shown in Table 1 and the average of 0.027mg/l as shown in Table 2 falls within the permissible range of W.H.O. (2004) standard. however, the parameter exceeds the W.H.O standard in some of the sample (1,3,4,5,6,7,8,9,11,12,13,14,15,16,17,18) as shown in Figure 6. Only sample 2 and 10 falls within the range of W.H.O (2004) which implies that these two samples does not have much groundwater contamination. The remaining sample that exceed W.H.O standard implies that the intake of water can cause delay in physical or mental development in children while kidney and high blood pressure in Adult.

Table 5. Result of the physical parameters of the water samples

Sample Code	Temp (^{0}c)	Conductivity (S/cm)	PH	TDS (mg/l)	Turbidity (FTU)
Well 01	24.9	22.3	6.72	1116.2	34
Well 02	23.7	17.5	6.32	1008.8	30
Well 03	21	20.4	6.75	1116.2	27
Well 04	23.7	18.8	6.75	983.4	22
Well 05	24	23.6	5.21	979.4	30
Well 06	20	22.4	6.82	876.3	25
Well 07	25	23	5.17	1028.7	26
Well 08	30.6	22	5.62	939.9	27
Well 09	24.9	14.3	5.72	1006.2	24
Well 10	24.7	15.5	6.02	1018.8	30
Well 11	23	10.4	6.05	1006.2	27
Well 12	23.7	18.8	6.05	883.4	22
Well 13	25	13.6	5.2	879.4	30
Well 14	20	12.4	6.02	876.3	25
Well 15	25	14	5.07	1000.7	26
Well 16	20.6	12	5.02	839.9	27
Well 17	25	23	5.17	1028.7	26
Well 18	30.6	22	5.62	939.9	27
MEAN	24.18	18.11	5.85	973.8	26.94

Table 6. Mean value of physical parameter compared with W.H.O.

Parameter	Temp (^{0}C)	Cond (S/cm)	PH	TDS (mg/l)	Turbidity (FTU)
Mean	24.18	18.1	5.85	973.8	26.9
W.H.O	25	10	8.5	1000	25

Arsenic (As): The result of arsenic ranges from 0.001mg/l to 0.088mg/l as shown in Table 1 and the average of 0.015mg/l as shown in Table 2 falls within the W.H.O standard. The concentration of this parameter is shown in Figure 6 which implies that they are no free exchangeable radicals of As in the groundwater.

Iron (Fe): The result of this parameter ranges from 0.11 to 1.01mg/l as shown in Table 1 and the average of 0.499mg/l as shown in Table 2. The high values of

this iron in the water samples is more than the permissible range specified by W.H.O standard which implies that the intake of the water can cause cancer.

Cadmiun (Cd): The amount of concentration of cadmium in this water sample ranges from 0.001 to 0.006mg/l as shown in Table 1 and the average of 0.0027mg/l as observed in Table 2.

The concentration of cadmium is shown in Figure 6, But in comparing the result with the specification of W.H.O, it is lesser than the permissible range of the standard and this implies that intake of this water will not have any negative effect on the human kidney.

Chlorine (Cl-): The result shows that concentration of chlorine in this water samples ranges from 120 to 167mg/l as shown in Table 3 and the average of 153.6mg/l as indicated in Table 4 which falls within the permissible range of W.H.O. (2004). The distribution of the value of chlorine for each water samples is shown in Figure 9. The negative impact of chlorine concentration will not occur because is within the threshold limit

Carbonate (Co): The low concentration of carbonate in this water samples is evidence that the leachate is not high in carbonate and therefore, the effect of carbonate on the intake of this water will be low. The distribution of this parameter is shown in Figure 8.

Physical parameters result

The physical properties were also analyzed to know the differences in the concentration level of the different physical components in the different samples taken which shows the characteristics of the different parameters that are measured and also compared with W.H.O standard to know the level of purity of the water and safety of the water samples for drinking. The physical parameter tested on this

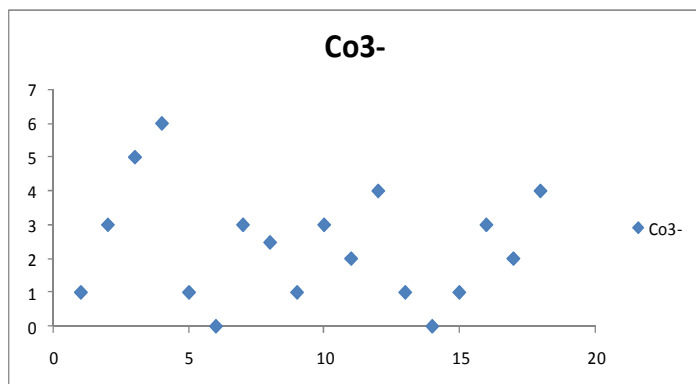samples include: Temperature (°C), total dissolved solid (TDS) (Mg/l), Ph, conductivity (S/Cm) and turbidity (FTU).

Fig. 8. Scatter diagram representing Co⁻₃

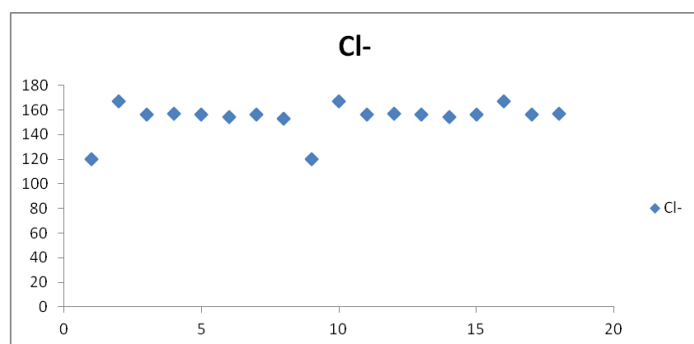**Fig. 9. Scatter diagram representing CL⁻**

*Temperature (°C)***:** The result of the temperature test carried out on these samples ranges from 20 to 30.6°C as shown in Table 5 and the average of 24.18°C as shown in Table 6. The concentration of temperature is shown in Figure 10. By comparing the result with W.H.O standard (2004) as shown in Figure 12, it falls within the permissible range of the standard.

Ph result **:** The result of the Ph obtained from this samples ranges from 5.02 to 6.82 as shown in Table 5 and the average of 5.85 as shown in Table 6. This result shows that some of the water samples are weakly acidic and in comparing their values with the W.H.O. standard as shown in Figure 13, the concentration of the Ph for various water samples is

shown in Figure 10 thus, it can be seen that the samples are fairly within the permissible limit of the standard. They are fair because the result is almost exceeding the limit of the standard and this implies that more leaching of this contaminant will result in the high value of Ph in the water.
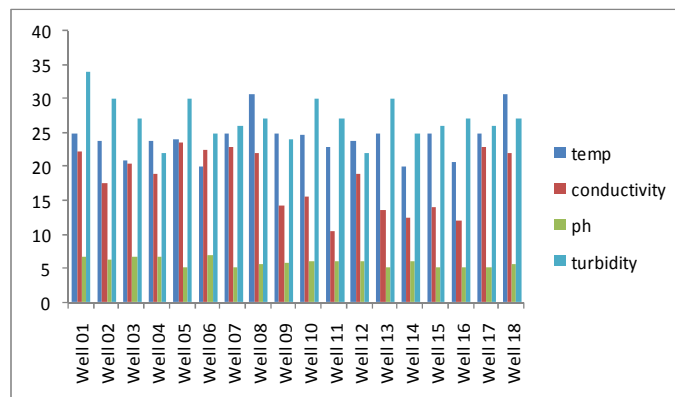

Fig. 10. Bar chart representing Temperature, Conductivity, pH and Turbidity.

Total dissolved solid (TDS) **:** The result of the total dissolved solid of these samples ranges from 839.9 to 1116.2mg/l as shown in Table 5 and an average of 973.8mg/l as shown in Table 6. However, the result is falls below the W.H.O. standard as shown in Figure 12 and this implies that some of the contaminant in the water samples is fairly dissolved. The fairly result obtained for these samples is an implication that more leaching of this contaminant will result in high values of the TDS

Conductivity (S/cm) **:** The result of conductivity of this samples ranges from 10.4 to 23.6 S/cm as shown in Table 5 and the average of 18.1S/cm as shown in Table 6. The degree of conductivity of the water samples is shown in Figure 10. The result shows low conductivity result beyond the W.H.O standard as shown in Figure 12 and this implies that the water samples in this area have low conductivity.

Table 7. World Health Organization Drinking Water Standard (2004)

Measured Parameter	Acceptable Level	Effect Above Level
Total dissolved solids(TDS)	Max 1000	Stomach discomfort
Cadmium	0.003mg/l	Kidney damage
Copper	2.0mg/l	Gastrointestinal, liver or kidney damage
Temperature	25^0C	Bone disease (pain and tenderness of the bone);Children may get mottled teeth
Arsenic	0.01mg/l	Skin damage or problems with circulatory system , and may have increased risk of getting cancer
Total Hardness	Max 150	Increase in blood pressure
Turbidity	Max 25	Nausea, cramps, diarrhea, and associated headaches
Chloride	Max 250mg/l	Eye/nose irritation and stomach discomfort
Calcium	Max 200mg/l	Indigestibility of fat in the body
Magnesium	Max 0.20mg/l	Gastrointestinal ,liver or kidney damage
Potassium	Max 50	Effect on blood pressure
Lead	0.01mg/l	Infant and children: Delay in physical and mental development, children could show slight deficits in attention span and learning ability
Ph	6.5-8.5	Rusting and cancer
Nickel	0.02mg/l	Cancer of lungs, nose, bone and dermatitis
Conductivity	Max 10S/cm	Anemia: liver, kidney or spleen damage, changes in blood
Iron	0.30mg/l	Rusting, cancer
Sulphate	Max 100mg/l	Allergic dermatitis
Sodium	Max 200mg/l	Increased risk of cancer
Zinc	3.0mg/l	Nausea, cramps, diarrhea, and associated headaches
Nitrate	50mg/l	Cyanosis, and asphysia (Blue baby syndrome),infant under three months
Phosphate	5.0mg/l	Anemia, liver, kidney or spleen damage, changes in blood

Turbidity : The concentration of turbidity of the water samples is shown in Figure 11. When comparing this result with W.H.O standard as shown in Figure 13, the result is found beyond the limit of which results in Nausea, cramps, diarrhea and associated headaches.
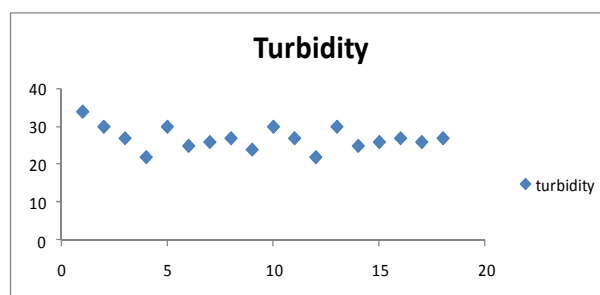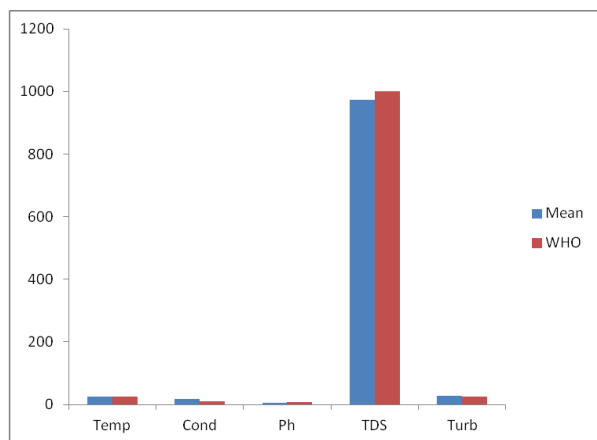

Fig. 11. Scatter diagram representing turbidity.

Fig. 12. Bar chart representing Table 6 compared with W.H.O.

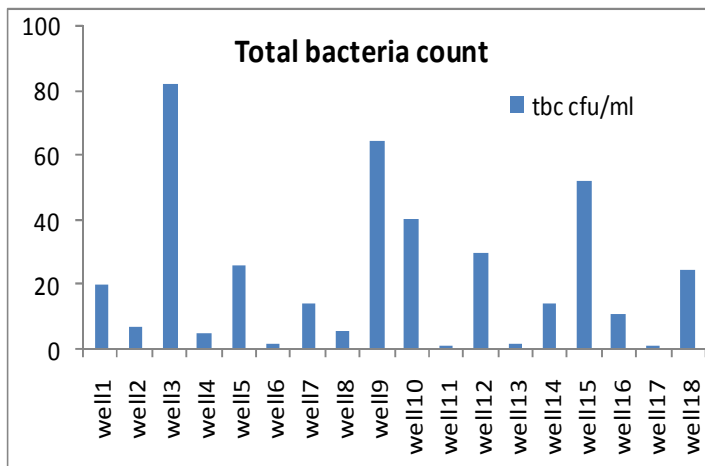## Table 8.Total bacterial count in the water samples

Sample Code	Total bacteria count (cfu/ml)	Longitude (E)	Latitude (N)	Elevation (m)
well1	$20 * 10^{-2}$	5.741	7.45	3000
well2	$7 * 10^{-2}$	5.742	7.457	3100
well3	$82 * 10^{-2}$	5.745	7.463	3100
well4	$5 * 10^{-2}$	5.741	7.470	3200
well5	$26 * 10^{-2}$	5.747	7.473	3300
well6	$2 * 10^{-2}$	5.742	7.483	3400
well7	$14 * 10^{-2}$	5.75	7.484	2100
well8	$6 * 10^{-2}$	5.754	7.476	2100
well9	$64 8 10^{-2}$	5.76	7.47	2200
well10	$40 * 10^{-2}$	5.765	7.483	3000
well11	$1 * 10^{-2}$	5.765	7.47	1800
well12	$30 * 10^{-2}$	5.765	7.47	1900
well13	$2 * 10^{-2}$	5.77	7.475	2000
well14	$14 * 10^{-2}$	5.765	7.465	1700
well15	$52 * 10^{-2}$	5.757	7.457	1600
well16	$11 * 10^{-2}$	5.758	7.447	1500
well17	$1 * 10^{-2}$	5.767	7.47	1900
well18	$25 * 10^{-2}$	5.790	7.465	3000

Microbial analysis result

Micro-organisms such as coliforms are mostly present in water. These organisms are found in most water samples, the microbial parameter analysis deals with the analysis of invisible organisms found in water. This parameter is also applicable as a part of the test carried out on the water sample in the study area. The micro-organism present in the water samples collected in the vicinity of the study area includes the following: *Staphylococcus* sp., *Streptococcus* sp., *Basillus* sp., *Clostridium* sp., *Escherichia coli* as shown in the table below. Careful attention is given to this micro-organism parameter and the infection caused by these micro-organisms to human being. The effect of each of this micro-organism is listed below However, *Staphylococcus* sp. are present in samples (1,2,4,7,8,9,11,12,18) as shown in the Table 9 and can affect many organs in the body system. The presence of this organism in the water sample can cause a wide variety of disease in humans through either toxin production or penetration. Some of the samples obtained within the vicinity of the dumpsite contain *Escherchia coli* such as sample (1,4,7,10,16,17) and as a result cause gastroenteritis urinary tract infection and neonatal meningitis. Sample (2, 4, 6, 9, 12, 13) contain streptococcus sp and as result cause erysipelas, necrotizing fasciltis, endocarditis, meningitis and bacterial pneumonia. *Clostridium* are found in sample (2, 5, 10, 13, 14, 18) and as a result cause infant botulision in humans between 1-3yrs of age and eventually paralyses the infant breathing muscles. It also causes diarrhea, overeating disease or pulpy kidney disease in sheep and goats, tetanus and also causes a fatal infection in exceptionally rare cases after medical abortion. *Micrococcus* Sp. are found in sample (3,5,7,11,13,15,18) and can cause skin infection.

Table 9. Micro-organism present in each sample

Sample	*Staphylococcus* Sp	*Escherichia coli*	*Streptococcus* Sp	*Basillus* Sp	*Clostridium* Sp	*Micrococcus* Sp
well1	◊	◊	○	○	○	○
well2	◊	○	◊	○	◊	○
well3	○	○	○	○	○	◊
well4	◊	◊	◊	○	○	○
well5	○	○	○	○	◊	◊
well6	○	○	◊	○	○	○
well7	◊	◊	○	○	○	◊
well8	◊	○	○	○	○	○
well9	◊	○	◊	○	○	○
well10	○	◊	○	○	◊	○
well11	◊	○	○	○	○	◊
well12	◊	○	◊	○	○	○
well13	○	○	◊	○	◊	◊
well14	○	○	○	○	◊	○
well15	○	○	○	○	○	◊
well16	○	◊	○	○	○	○
well17	○	◊	○	○	○	○
well18	◊	○	○	○	◊	◊
LEGEND ◊ Present ○ Absent						

Fig. 13. Bar chart showing microbial counts in the water.

Electrical Resistivity Imaging Result

Traverse 1

This transverse lies 20m away from the edge of the landfill and was taken along the roadside within the vicinity of the landfill. The inverted 2-D pseudosection obtained from the constant separation traversing (CST) survey is shown in Figure 14. In the pseudosection, high resistivity zone (red portion) between (1000-5000 ohms meter) existed near the surface with spreadlength between (130-170 m) and the depth of (5-8m) to the north and south of the section. This zone is interpreted as high resistive chemical compound and its migration near the surface is an indication that it is less dense. The result
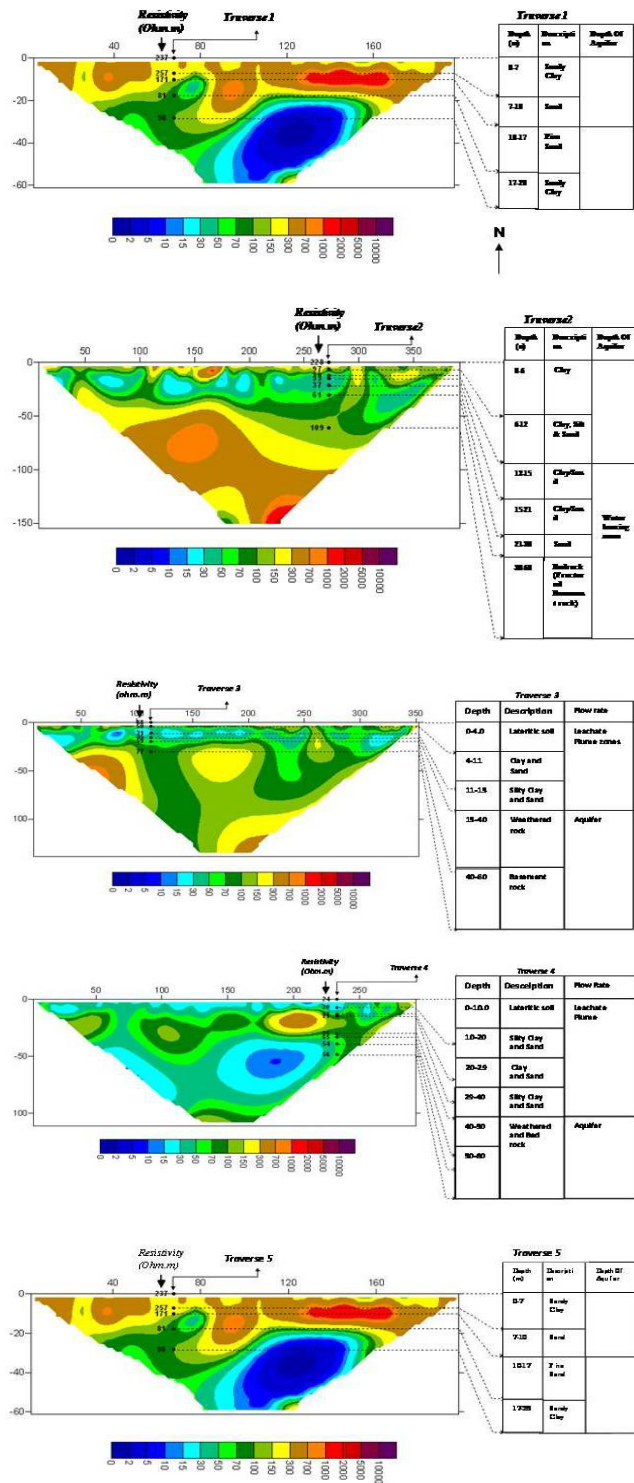
Fig. 14.Pseudosections of traverse 1-5 in the study area.

shows fine sand to coarse sand with resistivity value ranging from (81-257Ωm) with the depth of (10-17 m) and (7-10m) respectively. Underlying the zone of

high resistive chemical compounds is the zone of low resistivity (less than 15 Ωm) with depth ranging between (20-60m) and surface point between (90-150m). Between the high resistive chemical compound (These are zones of anomalously high resistivity, containing gaseous nature containing methane (CH_4), ammonia (NH_4), carbon dioxide (CO_2), and hydrogen sulphide (H_2S) from the biodegradation of organic wastes) and low resistivity zones are sand of varying size and thickness. The bluish portion shows zones of low resistivity (3-49Ωm) indicating contaminant leachate plumes changing from blue to light blue which reflect the changes in the concentration of the leachate as it seeps down due to the filtration by the sediment while the yellow portion shows zones of water bearing (sands).The migration of the contaminant leachate plumes to the bottom is an indication that it is denser. The greenish portion within the interpreted pseudosection of the transverse in the area of the study with low resistivity (less than 80 Ωm) represents trash cells area in the study area. The trash cell zone is area where dump waste materials are located and leachate activity in the environment will be very high. The deep blue colour band shows that the leachate is highly concentrated in the area while the light blue colour bands shows the characteristic of leachate polluted area. The cover material in this transverse is very thick and also existed within the upper layer. They include sandy clay, sand, fine sand with a depth ranging from (0-28m).

Traverse 2

The inverted 2-D pseudosection as shown in Figure 14 delineated three subsurface layer. These are the top soil, weathered layer and basement bedrock. The result shows that the top soil have virtually merged with the weathered layer due to overlapping low/high resistivity values. The top soil is characterized with light bluish, greenish and very low yellow colour

bands. The greenish colour band with low resistivity (less than 80 Ωm) representing trash cell area of the study area in which dump waste are located existed at a depth of (10-30m) with a surface point of (10-350m).The bluish colour band existed between the depth of (10-30m) and surface point of (30-300m) which indicates leachate saturation. The result shows the intercalation of clay and clay sand with resistivity ranging from (39-97Ωm) and (37-61Ωm) respectively which prevents these leachate from migrating downwards to contaminate the water bearing zone (yellow band).The second layer is the weathered layer characterized by yellow colour band indicating the water bearing zone (sand).The last layer is the basement bedrock characterized by brown – red colour ranging from (30-60m).The light blue colour bands indicates the occurrence of leachate but the concentration is not very high.

Traverse 3

In this transverse, the leachate effect is mapped out in the region with relatively low resistivity (29-39 Ωm) which is isolated in a light blue colour band as shown in Figure 14.The low resistivity variation is indicative of the degree of decomposition of the refuse material and are indication of the saturated zones starting from the ground surface. The contaminated leachate plumes existed at the surface point of (0-250m) and (261-350m) and with a depth of (0-15m).The presence of the leachate could not be seen at the surface point of (251-260m) along the surface of the transverse. The trash cell area (greenish portion) representing areas where dump waste are located existing within the depth of (30-120m) infilterated the water bearing zone (yellow portion). The water bearing zone existed at the depth of (30-70m) and at the surface point of (150-200m).The isolation of these trash cell zone (greenish portion) in the transverse suggest that the subsoil and groundwater may have been contaminated by the leachate. The

result also show that the cover material is very thick, the cover material includes lateritic soil, clay and sand, silty clay and sand with depth of (0-4m), (4-11) and (11-15m) respectively.

Traverse 4

The interpreted pseudosection as shown in Figure 14 reveals two pronounced zones. These include the top zone and the groundwater (water bearing) zone. The top zone (light blue) is indicated as the leachate plume concentration with resistivity ranging from (20-56 Ωm) and at the depth of (40-100m).The result shows that the cover material of the dump site have been infiltrated by the contaminant leachate plumes. The lower the resistivity of this zone, the higher the conductivity and the more porous they are and the more permeable the underline soil. The cover material such as sand at the depth of (10-29m) signifies the groundwater zone (yellow portion) which has been partly infiltrated by the contaminant leachate plume. The lithology of this dumpsite enhances the migration of the leachate plume, this is because sand is highly porous and highly permeable therefore allowing the leachate to migrate downwards. The migration of the contaminant leachate plume to the bottom is an indication that it is denser. The trash cell zone (greenish portion) which represent areas where dump waste are located are moving in the direction of the leachate plumes which signifies characteristic polluted area. The characteristic polluted area influenced by the leachate plumes also infiltrated the groundwater zone therefore moving in the same direction as the leachate plume.

Traverse 5
This transverse lies 25m away from the edge of the landfill and was taken along the roadside within the vicinity of the landfill. The inverted 2-D pseudosection obtained from the constant separation

transversing (CST) survey is shown in Figure 14. In the pseudosection, high resistivity zone (red portion) between (1000-5000 ohms meter) existed near the surface with spread length between (130-170 meters) and the depth of (5-8 meters) to the north and south of the section. This zone is interpreted as high resistive chemical compound and its migration near the surface is an indication that it is less dense. The result shows fine sand to coarse sand with resistivity value ranging from (81-257 ohms meter) with the depth of (10-17 m) and (7-10m) respectively. Underlying the zone of high resistive chemical compounds is the zone of low resistivity (less than 15 ohms meter) with depth ranging between (20-60m) and surface point between (90-150m).Between the high resistive chemical compound and low resistivity zones are sand of varying size and thickness. The bluish portion shows zones of low resistivity (contaminant leachate plumes) changing from blue to light blue reflect the changes in the concentration of the leachate as it seeps down due to the filtration by the sediment. The yellow portion shows zones of water bearing (sands).The migration of the contaminant leachate plumes to the bottom is an indication that it is denser. The greenish portion within the interpreted pseudosection of the transverse in the area of the study with low resistivity (less than 80 ohms meter) represent trash cells area in the study area. The trash cell zones are areas where dump waste materials are located and leachate activity in the environment will be very high. The deep blue colour band shows that the leachate is highly concentrated in the area while the light blue colour bands shows the characteristic of leachate polluted area. The cover material in this transverse is very thick and also existed within the upper layer. They include sandy clay, sand, fine sand with a depth ranging from (0-28m).

Conclusions

The combinations of Microbial, Physico-chemical and 2D ERT analyses of water samples from existing hand dug wells have been successfully used for the detection of groundwater contamination due to municipal solid waste in the study area. The 2D electrical resistivity models successfully delineated the lateral and vertical extent of the contaminated zones as well as fractures as subsurface contaminant pathways. The result of the 2-D resistivity imaging shows the various lithological units in the study site based on the respective depths of investigation. The geologic interpretation shows that the site is dominantly underlain. by clay and sandy formation of varying grain size which constitute the hydrogeologic unit of the area. The study showed that parts of the dumpsite had been polluted. This contamination was also observed to have infiltrated to a depth of 60m in the dumpsite. This could pose serious health risk to the inhabitant of the area who depends largely on the wells and shallow boreholes for their drinking water supply. The 2D resistivity models were unable to distinguish the sources of the contaminant as either resulting from electrolytic or metallic invasion since they have similar resistivity.

However the result of the microbial analysis carried out on the water samples collected from the hand dug wells in the study area reveals some micro-organism such as *staphylococcus* sp., *Escherichia coli, Streptococcus* sp*., Basillus* sp., *Clostridium* sp*., Mycobacterium* sp., *and Micrococcus* sp. The occurrence of these micro-organisms in the water sample is evidence of the leachate which result in groundwater contamination. The presence of this organism in water has great infection on people taking the water. The infection includes: diarrhea, skin infection, kidney disease, liver disease and high blood pressure etc.

The physico-chemical result is also an evidence to prove the concentration of the leachate in the area of study. The study revealed that the concentration of waste materials in the landfill site had systematically polluted the soil and groundwater over time. The effect of such pollution as determined from the study declined away from the polluting source .This implied that the contamination of groundwater was more dependent on proximity to the dump site. The observation of elevated level of Ca, Mg, K, Na and the presence of some conventional contaminant above the W.H.O permissible limit in some of the water samples is an indication of uncontrolled accumulation of leachate over time at the landfill site which represents a significant threat to the ground water quality. The finding obtained from this assessment have shown that groundwater of the study area is unreliable for drinking water supply purposes and therefore puts emphasis on the need to improve on waste management practices and construct properly engineered sanitary landfill site to curtail the pollution of groundwater.

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